CLAIMS

What is claimed is:

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1. A method of modeling a process system comprising the steps of:

(a) modeling a subject process system with an initial model;

(b) coupling to the subject process system a multivariable process control system that utilizes said initial model, to control the subject process system;

(c) tuning said multivariable process control system for stable operation of the subject process system; and

(d) using data generated from said multivariable process control system, generating an improved model of the subject process system, said steps of tuning and generating effectively perturbing the subject process system to generate data for model identification of the subject process system.

2. A method as claimed in Claim 1 further comprising repeating steps (b) through (d) with said improved model as the initial model such that a further improved model is generated.

3. A method as claimed in Claim 1, wherein the steps of tuning and generating are accomplished in parallel with step testing.

4. A method as claimed in Claim 1, wherein any combination of the steps is done remotely via a high speed communication link and digital processor, such that a reduction in engineering supervision is enabled.

5. A method as claimed in Claim 1, wherein the multivariable process control system employs a constrained, model-based controller.

6. A method as claimed in Claim 1, wherein step (a) of modeling said subject process system includes one of:

using an existing model from a potentially different but similar process system;

deriving a model from a non-model based process control system;

deriving a model from a manual step test of said subject process system; and

deriving a model from engineering knowledge of said subject process system.

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7. A method as claimed in Claim 1, wherein step (b) of coupling to said subject process system includes the multivariable process control system employing an explicit or implicit model, where an explicit model is a model describable by a mathematical equation, and where an implicit model is a model not describable by a mathematical equation.

8. A method as claimed in Claim 7, wherein said multivariable process control system employs at least one of:

sliding mode control;

switching mode control structures; and

variable structure control.

9. A method as claimed in Claim 1, wherein step (b) of coupling to said subject process system includes constructing and controlling equivalent system manipulated variables, where values of said equivalent system manipulated variables are equal to the initial model predicted values when controlled variables of the subject process system are within subject process limit values.

10. A method as claimed in Claim 1, wherein step (b) of coupling to said subject process system includes computing process control action for controlled variables and manipulated variables in accordance with an objective function *J*.

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11. A method as claimed in Claim 10, wherein said objective function *J* is extremized.

12. A method as claimed in Claim 1, wherein step (b) of coupling to said subject process system includes using target values calculated via a robust steady-state target calculation.

13. A method as claimed in Claim 1, wherein step (b) of coupling to said subject process system includes augmenting the initial model with shadow system controlled variables, where shadow system controlled variables are mathematically and functionally equivalent to system manipulated variables which may be treated as system controlled variables.

14. A method as claimed in Claim 13, wherein step (b) of coupling to said subject process system includes moving or stepping one or more system manipulated variables or said shadow system controlled variables simultaneously.

15. A method as claimed in Claim 14, wherein step (b) of coupling to said subject process system includes moving or stepping one or more system manipulated variables or said shadow system controlled variables for a fixed or varying amounts of time.

16. A method as claimed in Claim 15, wherein step (b) of coupling to said subject process system includes superimposing a pseudo-random binary sequence (PRBS) on said moves or steps of the system manipulated variables and said shadow system controlled variables.

17. A method as claimed in with Claim 15, wherein step (b) of coupling to said subject process system includes normalizing a system manipulated variable-system controlled variable gain relation to unity and using the normalized gain relation as the shadow system controlled variable.

18. A method as claimed in Claim 13, wherein step (b) of coupling to said subject process system includes adjusting shadow system controlled variables targets to prevent shadow system controlled variables from violating subject process control variable limits.

19. A method as claimed in Claim 9, wherein said step of controlling equivalent system manipulated variables is in accordance with one of:

an objective function *J*;

a simultaneous moving of one or more shadow system controlled variables or system manipulated variables;

for an amount of time, moving of one or more shadow system controlled variables or system manipulated variables;

a superimposed PRBS sequence;

a normalized system manipulated variable-system controlled variable gain, the normalized gain being normalized to unity and used as the shadow system controlled variable; and

an adjustment of shadow system controlled variables targets to prevent shadow system controlled variables from violating subject process control variable limits.

20. A method as claimed in Claim 1, wherein step (b) of coupling to said subject process system includes imposing a dead zone on controlled variables of the multivariable process control system.

21. A method as claimed in Claim 20, wherein the dead zone is computed by accumulating relatively small manipulated variable control action from said multivariable process control system and implementing the control action when summed control action reaches a predefined threshold.

22. A method as claimed in Claim 21, wherein the controlled variables are filtered to attenuate high frequency noise.

23. A method as claimed in Claim 20, wherein the dead zone is generated by modifying mathematical formulation of the multivariable process control system.

24. A method as claimed in Claim 23, wherein the mathematical formulation employs discrete or binary system manipulated variables.

25. A method as claimed in Claim 20, wherein the dead zone is generated by an analogue to digital converter.

26. A method as claimed in Claim 20, wherein the dead zone is generated by pulse width modulation.

27. A method as claimed in Claim 1, wherein step (b) of coupling to said subject process system includes creating a time varying, almost periodic limit cycle of manipulated variables of the subject process system.

28. A method as claimed in Claim 27, wherein system controlled variables are filtered to attenuate low frequency noise.

29. A method as claimed in Claim 1, wherein step (b) of coupling to said subject process system includes calculating suitable targets for system manipulated variables of the subject process system.

30. A method as claimed in Claim 29, wherein said suitable targets for system manipulated variables are chosen manually by a human operator.

31. A method as claimed in Claim 29, wherein said suitable targets for system manipulated variables are determined by one of:

a middle value of process control limit values for controlled variables of the subject process system;

a partial least squares analysis;

a principle components analysis; and

a value furthest away from process control limit values of both manipulated variables and controlled variables of the subject process system.

32. A method as claimed in Claim 29, wherein the suitable targets for system manipulated variables are automatically determined and implemented by a digital processing system, in a manner that enables reduction of engineering supervision.

33. A method as claimed in Claim 29, wherein the manipulated variables are stepped or moved in a random way about the suitable targets while keeping said manipulated variables and controlled variables of the subject process system within process control limit values.

34. A method as claimed in Claim 1, wherein step (c) of tuning said multivariable process control system includes adjusting internal variables of the multivariable process control system in a manner that improves process control action and ensures process system safety.

35. A method as claimed in Claim 34 wherein said adjusting reduces feedback correlation between control action of the multivariable process control system and disturbances of the subject process system.

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36. A method as claimed in Claim 1, wherein step (b) of coupling to said subject process system includes computing process control action in accordance with subject process variable limit values and subject process system disturbances, wherein subject process system disturbances are unmeasured extraneous influences affecting the subject process system and not captured in the initial model.

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37. A method as claimed in Claim 36 further comprising adjusting internal tuning variables such that feedback correlation between control action of the multivariable process control system and disturbances of the subject process system is reduced.

38. A method as claimed in Claim 1, wherein step (d) of using data and generating an improved model includes using a system identification algorithm and analyzing values of manipulated variables and controlled variables of the subject process system to create an improved model.

39. Apparatus for modeling a process system, comprising:

an initial model of a subject process system;

a multivariable process controller coupled to the subject process system, the multivariable process controller utilizing the initial model to control the subject process system; and

computer means coupled to the multivariable process controller, the computer means effectively perturbing the subject process system, to generate data for model identification of the subject process system, by (i) tuning the multivariable process controller for stable operation of the subject process system and (ii) using data generated by the multivariable process controller, generating an improved model of the subject process system.

40. Apparatus as claimed in Claim 39 wherein:

the multivariable process controller utilizes the improved model to control the subject process system; and

the computer means repeatedly tunes the multivariable process controller and generates further improved models of the subject process system.

41. Apparatus as claimed in Claim 39, wherein the multivariable process controller tuning and generating are accomplished in parallel with step testing.

42. Apparatus as claimed in Claim 39, wherein the initial model, the multivariable process controller and computer means are coupled to a high speed communication link enabling remote operation.

43. Apparatus as claimed in Claim 39, wherein the computer means enables engineering supervision to be gradually reduced.

44. Apparatus as claimed in Claim 39, wherein the initial model is one of:

an existing model from a potentially different but similar process system;

a model derived from a non model-based process control system;

a model derived from a manual step test of the subject process system;

a model derived from engineering knowledge of the subject process system.

45. Apparatus as claimed in Claim 39, wherein the multivariable process controller is a constrained, model-based system.

46. Apparatus as claimed in Claim 39, wherein the multivariable process controller employs an explicit or implicit model, where an explicit model is a model describable by a mathematical equation, and where an implicit model is a model not describable by a mathematical equation.

47. Apparatus as claimed in Claim 46, wherein said multivariable process controller employs one of:

    sliding mode control;
    switching mode control structures; and
    variable structure control.

48. Apparatus as claimed in Claim 39, wherein the computer means constructs and controls equivalent manipulated variables of the subject process system.

49. Apparatus as claimed in Claim 39, wherein the computer means computes process control action for controlled variables and manipulated variables in accordance with an objective function *J*.

50. Apparatus as claimed in Claim 49, wherein said objective function *J* is extremized.

51. Apparatus as claimed in Claim 39, wherein the multivariable process controller uses targets calculated via a robust steady-state target calculation.

52. Apparatus as claimed in Claim 39, wherein the computer means augments the initial model with shadow system controlled variables, where shadow system controlled variables are mathematically and functionally equivalent to system manipulated variables that may be treated as system controlled variables.

53. Apparatus as claimed in Claim 52, wherein the multivariable process controller moves or steps one or more system manipulated variables or said shadow system controlled variables simultaneously.

54. Apparatus as claimed in Claim 53, wherein the multivariable process controller moves or steps one or more system manipulated variables or said shadow system controlled variables for a fixed or varying amounts of time.

55. Apparatus as claimed in Claim 54, wherein the multivariable process controller superimposes a pseudo-random binary sequence (PRBS) on said moves or steps of the system manipulated variables and said shadow system controlled variables.

56. Apparatus as claimed in Claim 54, wherein the multivariable process controller normalizes a system manipulated variable-system controlled variable gain relation to unity and uses the normalized gain relation as the shadow system controlled variable.

57. Apparatus as claimed in Claim 52, wherein the computer means further adjusts shadow system controlled variables targets to prevent shadow system controlled variables from violating subject process control variable limits.

58. Apparatus as claimed in Claim 48, wherein the computer means controls the equivalent manipulated variables in accordance with one of:

an objective function *J*;

a simultaneous moving of one or more shadow system controlled variables or system manipulated variables;

for an amount of time, moving of one or more shadow system controlled variables or system manipulated variables;

a superimposed PRBS sequence;

a normalized system manipulated variable-system controlled variable gain, the normalized gain being normalized to unity and used as the shadow system controlled variable; and

an adjustment of shadow system controlled variables targets to prevent shadow system controlled variables from violating subject process control variable limits.

59. Apparatus as claimed in Claim 39, wherein the computer means imposes a dead zone on controlled variables of the multivariable process controller.

60. Apparatus as claimed in Claim 59, wherein the dead zone is computed by accumulating small manipulated variable control action from said multivariable process controller and implementing the control action when summed control action reaches a predefined threshold.

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61. Apparatus as claimed in Claim 60, wherein the controlled variables are filtered to attenuate high frequency noise.

62. Apparatus as claimed in Claim 59, wherein the said dead zone is generated by modifying mathematical formulation of the multivariable process controller.

63. Apparatus as claimed in Claim 62, wherein the mathematical formulation employs discrete or binary system manipulated variables.

64. Apparatus as claimed in Claim 59, wherein the dead zone is generated by an analogue to digital converter.

65. Apparatus as claimed in Claim 59, wherein the said dead zone is generated by pulse width modulation.

66. Apparatus as claimed in Claim 39, wherein the computer means creates a time varying almost periodic limit cycle of system manipulated variables.

67. Apparatus as claimed in Claim 66, wherein system controlled variables are filtered to attenuate low frequency noise.

68. Apparatus as claimed in Claim 39, wherein the computer means calculates suitable targets for manipulated variables of the subject process system.

69. Apparatus as claimed in Claim 68, wherein said suitable manipulated variable targets are chosen manually by a human operator.

70. Apparatus as claimed in Claim 68, wherein the computer means calculates suitable manipulated variable targets according to one of:

a middle value of process control limit values for controlled variables of the subject process;

a value furthest away from process control limit values for both manipulated variables and controlled variables of the subject process system;

a partial least squares analysis; and

a principle components analysis.

71. Apparatus as claimed in Claim 68, wherein the manipulated variables are stepped or moved in a random way about the said suitable targets while keeping said manipulated variables and controlled variables of the subject process system within said process control limit values.

72. Apparatus as claimed in Claim 39, wherein the computer means adjusts internal variables of the multivariable process controller.

73. Apparatus as claimed in Claim 72 wherein the computer means adjusting reduces feedback correlation between control action of the multivariable process controller and disturbances of the subject process system.

74. Apparatus as claimed in Claim 39, wherein the computer means further computes process control action in accordance with subject process variable limit values and subject process system disturbances, wherein subject process system disturbances are unmeasured extraneous influences affecting the subject process system and not captured in the initial model.

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75. Apparatus as claimed in Claim 74 wherein the computer means further adjusts internal tuning variables such that feedback correlation between control action of the multivariable process controller and disturbances of the subject process system is reduced.

76. Apparatus as claimed in Claim 39, wherein the computer means uses a system identification algorithm to analyze values of manipulated variables and controlled variables of the subject process system to create an improved model.

77. Apparatus as claimed in Claim 39, wherein:

the multivariable process controller includes a closed-loop process control system that generates values for manipulated variables and controlled variables of the subject process system for model identification; and

the generated data includes an open-loop process control system.

78. A controller comprising:

a digital processor; and

a program storage device that is readable by said digital processor and that encodes a program of instructions for performing a method of modeling a subject process system comprising the steps of:

(a) modeling the subject process system with an initial model;

(b) controlling the subject process system with a multivariable process control system that utilizes said initial model;

(c) tuning said multivariable process control system for stable operation of the subject process system; and

(d) using data generated from said multivariable process control system, generating an improved model of the subject process system, said steps of tuning and generating effectively perturbing the subject process system to generate data for model identification of the subject process system.

79. A controller as claimed in Claim 78 wherein step (b) of controlling the subject process system includes augmenting the initial model with shadow system controlled variables, where shadow system controlled variables are mathematically and functionally equivalent to system manipulated variables which may be treated as system controlled variables.

80. A controller as claimed in Claim 79 wherein step (b) of controlling the subject process system includes moving or stepping one or more system manipulated variables or said shadow system controlled variables simultaneously.

81. A controller as claimed in Claim 80 wherein step (b) of controlling the subject process system includes superimposing a pseudo-random binary sequence (PRBS) on said moves or steps of the system manipulated variables and said shadow system controlled variables.

82. A controller as claimed in Claim 78 wherein step (b) of controlling the subject process system includes imposing a dead zone on controlled variables of the multivariable process control system.

83. A controller as claimed in Claim 78 wherein step (b) of controlling the subject process system includes calculating suitable targets for system manipulated variables of the subject process system.

84. A controller as claimed in Claim 78 wherein:

step (b) includes a closed-loop process control system that generates values for manipulated variables and controlled variables of the subject process system in accordance with step (d); and

the generated data includes an open-loop process control system.

85. A program storage device encoding a machine-readable copy of a program of instructions, said program of instructions being executed by a computer for performing a method of modeling a subject process system comprising the steps of:

(a) modeling a subject process system with an initial model;

(b) controlling the subject process system with a multivariable process control system that utilizes said initial model;

(c) tuning said multivariable process control system for stable operation of the subject process system; and

(d) using data generated from said multivariable process control system, generating an improved model of the subject process system, said steps of tuning and generating effectively perturbing the subject process system to generate data for model identification of the subject process system.

86. A program storage device of Claim 85 wherein:

step (b) includes a closed-loop process control system that generates values for manipulated variables and controlled variables of the subject process system in accordance with step (d); and

the generated data includes an open-loop process control system.

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